Neurologic findings caused by ossification of ligamentum flavum at the thoracolumbar junction

Kazuhiro Fujimoto, Tsukasa Kanchiku, Yasuaki Imajo, Hidenori Suzuki, Yuichiro Yoshida, Norihiro Nishida, Masahiro Funaba, Toshihiko Taguchi

Department of Orthopaedic Surgery, Yamaguchi University Graduate School of Medicine, Ube, Yamaguchi, Japan

Objective: To evaluate neurologic findings caused by a single ossification of ligamentum fravum (OLF) and identify the level of the lumbar segment of spinal cord.
Design: Retrospective study.
Methods: Subjects were 28 patients with a single OLF at T10-11 level (15 patients), T11-12 (11), and T12-L1 (2). The tip of the conus medullaris was assessed using computed tomographic myelography or magnetic resonance imaging. Neurologic evaluations were performed for patellar tendon reflex (PTR), sensory disturbance, and motor weakness.
Results: The tip of the conus medullaris was located at the L1 vertebral body level. At the T10-11 level, all patients showed hyperreflexia of PTR. Sensory disturbance was observed for L1 dermatome and weakness of the iliopsoas was noted. At the T11-12 level, 8 of 11 patients didn't show hyperreflexia of PTR. Sensory disturbance was observed for L5 dermatome and weakness of the tibialis anterior was noted. At the T12-L1 level, all patients showed normal reflex of PTR, sensory disturbance of L5 dermatome, and weakness of the tibialis anterior.
Conclusion: With regard to the relationship between PTR and OLF level, all patients at the T10-11 level showed involvement of the L3 segment of spinal cord proximally. On the other hand, most patients at the T11-12 level showed involvement of the L4 segment of spinal cord distally. From all neurologic findings, we confirmed the presence of the L4 segment of spinal cord from the lower third of T11 vertebral body to the T11-12 intervertebral disc level.

Keywords: Pathologic ossification, Ligamentum flavum, Neurologic examination, Thoracic diseases, Spinal cord compression

Introduction

Clinicians face difficult decisions when patients present with a combination of compressive myelopathy at the thoracolumbar junction and lumbar spinal canal stenosis (LSS), as revealed by magnetic resonance imaging (MRI). There were a few reports of patients who suffered unexpected acute neurologic deteriorations after lumbar decompressive surgery under these pathology.[1,2] Thoracolumbar junction disorders show a variety of signs and symptoms due to the complexity of the spinal cord, cauda equina, and nerve roots. It is important to understand the level of the lumbar segment of spinal cord to correctly diagnose thoracolumbar junction disorders.

Correspondence to: Kazuhiro Fujimoto, Department of Orthopaedic Surgery, Yamaguchi University Graduate School of Medicine, 1-1-1 Minami Kogushi, Ube City, Yamaguchi, 755-8505, Japan. Email address: kafuji@yamaguchi-u.ac.jp

Segments of spinal cord from L4 to S2 are called the epiconus, while segments of spinal cord from S3 to S5 are called the conus medullaris. Generally, the epiconus is at the T12 vertebral body level and the conus medullaris extends from the T12-L1 intervertebral disc level to the L1 vertebral body level.[3,4] Previous studies included patients with ossification of ligamentum flavum (OLF), disc herniation, and vertebral fracture of the spine.[5] However, neurologic findings can differ slightly depending on how the spinal cord is compressed and the existence of previous vertebral fractures.[6]

Previous studies in cadavers reported the following lengths for each lumbar and sacral segments of spinal cord. We measured heights of vertebral bodies and intervertebral discs using computed tomographic myelography (CTM) and MRI, and designed an original model of the spine and spinal cord at the thoracolumbar junction to identify the level of the lumbar segment of spinal

DOI 10.1080/10790268.2015.1118185

cord.The aim of this study is to evaluate neurologic findings caused by a single OLF at the thoracolumbar junction in the absence of previous vertebral fracture, thus allowing identification of the true level of the lumbar segment of spinal cord.

Materials and methods

Subjects were 28 patients (19 men and 9 women) with a single OLF from T10-11 to T12-L1 who underwent operative treatment at our hospital. Their ages at surgery ranged from 38 to 85 years (mean age, 65 years). All study participants provided informed consent, and the study design was approved by an ethics review board of Yamaguchi University Graduate School of Medicine. Patients with previous vertebral fracture, previous spinal surgery, or spinal deformity were excluded from the present study.

The location of the tip of the conus medullaris was assessed using CTM and MRI. It was classified into four levels, with the vertebral body being divided into three equal portions (upper, middle, and lower third) and the intervertebral disc defined as a separate level (Figure 1). The compressive lesion was also assessed using CTM and MRI and was classified into three groups: the T10–11 level (15 patients), T11–12 level (11 patients), and T12–L1 level (2 patients). OLF at each level was all confirmed intraoperatively. The mean heights of vertebral bodies and intervertebral discs measured using CTM and MRI were as follows: T10 vertebral body, 21.6 mm; T11 vertebral body, 23.6 mm; T12 vertebral body, 25.6 mm; and L1 vertebral body, 26.2 mm; T10–11 intervertebral disc, 5.1 mm; T11–12 intervertebral disc, 5.3 mm; and T12–L1 intervertebral disc, 5.6 mm. Previous studies in cadavers reported the lengths of each lumbar and sacral segment of the spinal cord as follows: L2, 11 mm; L3, 10 mm; L4, 8.9 mm; L5, 9 mm; S1, 7.7 mm; and S2-5, 34.9 mm.[7–9] The length was defined as the origin of dorsal rootlets separated from the spinal cord (Figure 2). The model of the spine and spinal cord at the thoracolumbar junction was designed using these values (Figure 3).

Neurologic evaluations were performed for the patellar tendon reflex (PTR), sensory disturbance, and motor

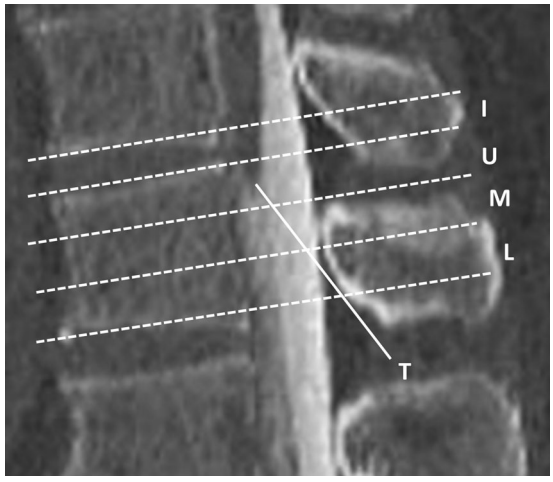

Figure 1 Location of the tip of the conus medullaris (T) was classified into 4 levels, with the vertebral body being divided into three equal portions (upper (U), middle (M), and lower (L) third) and the intervertebral disc (I) defined as a separate level.

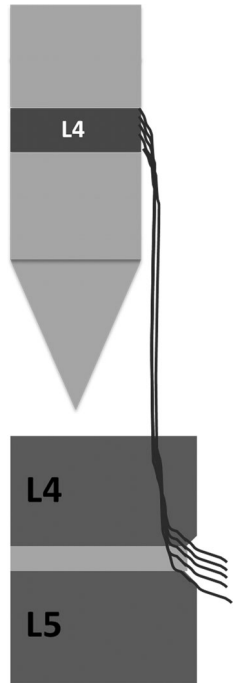

Figure 2 The length of the L4 segment of spinal cord was showed. The length of each segment of spinal cord was defined as the origin of dorsal rootlets separated from the spinal cord.

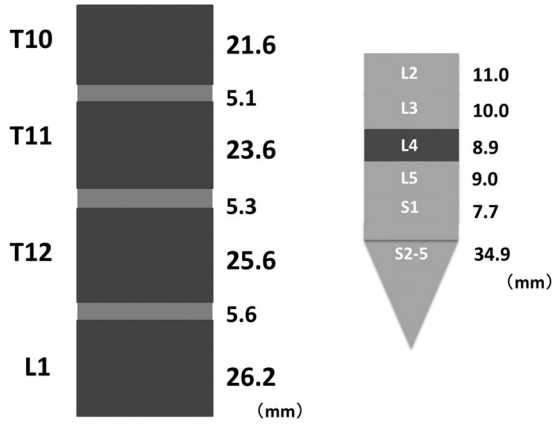

Figure 3 The model of spine and spinal cord at the thoracolumbar junction was designed using these values in this figure.

weakness. PTR was classified as hyperreflexia, normal reflex, hyporeflexia, or areflexia, with the last three being defined as nonhyperreflexia. Sensory disturbance was evaluated by the pin-prick test using Brain and Walton's dermatome[10] and motor weakness was evaluated by manual muscle testing. Spine surgery specialist-sexamined all patients preoperatively.

Statistical analysis

The χ^2 test was used for statistical analysis, with a probability value <0.05 being considered as significant. The free software program R version 2.14 (http://www.rproject.org/) was used for statistical analysis.

Results

The location of the tip of the conus medullaris ranged from the lower third of T12 to the lower third of L2 vertebral body level. It was most commonly located at the L1 vertebral body level (18/28, 64%; Figure 4).

At the T10–11 level, all patients showed hyperreflexia of PTR, with a sensitivity of 100% and specificity of 77%. There was a significant difference between T10–11 and other intervertebral disc levels with regards to hyperreflexia of PTR ($P < 0.01$). Sensory disturbance was observed for L1 dermatome in three patients, with a sensitivity of 20% and specificity of 92%. There was no significant difference between T10–11 and other intervertebral disc levels with respect to hypesthesia of L1 dermatome ($P = 0.35$). Weakness of the iliopsoas was noted in eight patients, with a sensitivity of 54% and specificity of 92%. There was a significant difference between T10–11 and other intervertebral disc levels in terms of weakness of the iliopsoas ($P < 0.01$). In this group, 8 of 15 patients showed the conus position at L1 vertebral body level. Three patients showed conus position proximally, and 4 patients showed it distally. One patient with distal conus position showed marked motor weakness of tibialis anterior however all patients with proximal or distal conus position showed hyperreflexia of PTR.

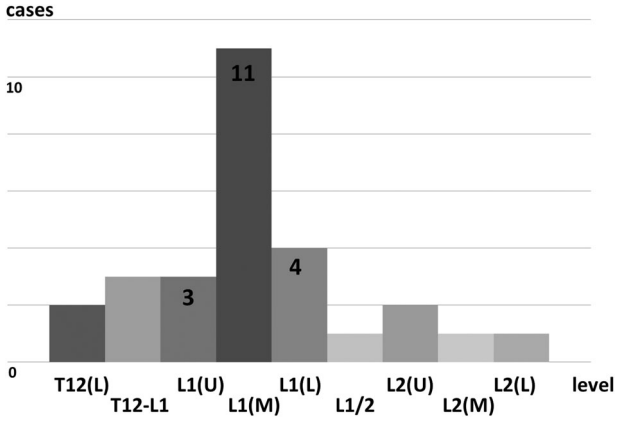

Figure 4 The location of the tip of the conus medullaris ranged from the lower third of T12 to lower third of L2. It was most commonly located at the L1 vertebral body level (64%).

At the T11–12 level, 8 of 11 (73%) patients did not show hyperreflexia of PTR, with a sensitivity of 73% and specificity of 88%. There was a significant difference between T11–12 and other intervertebral disc levels with regards to nonhyperreflexia of PTR ($P < 0.01$). Sensory disturbance for the L5 dermatome was observed in six patients, with a sensitivity of 55% and specificity of 65%. There was no significant difference between T11–12 and other intervertebral disc levels with respect to hypesthesia of L5 dermatome ($P = 0.31$). Weakness of the tibialis anterior was noted in four patients, with a sensitivity of 36% and specificity of 88%. There was no significant difference between T11–12 and other intervertebral disc levels in terms of weakness of the tibialis anterior ($P = 0.12$). In this group, 8 of 11 patients showed the conus position at the L1 vertebral body level. Two patients showed conus position proximally, and one patient showed it distally. One patient with distal conus position showed marked motor weakness of iliopsoas.

At the T12–L1 level, all patients showed normal reflex of PTR. Sensory disturbance was observed for the L5 dermatome in all patients. Weakness of the tibialis anterior was also observed in all patients.

Discussion

It is widely accepted that the tip of the conus medullaris is at the middle third of the L1 vertebral body level using MRI in normal living subjects, although locations ranging from T11 to L3 vertebral body level have been reported.[11–14] Majority of reports concluded that no significant difference in conus position was seen between male and female or with increasing age.[12–14] Patients with previous vertebral fracture were excluded from these studies. In addition, we evaluated spinal deformity or number of cervical, thoracic, and lumbar vertebrae correctly using CTM in all patients because the presence of spinal deformity or lumbosacral transitional vertebrae affected the variation of the tip of the conus medullaris.[15,16] Similarly, in our study, the tip of the conus medullaris was most commonly located at the L1 vertebral body level. On the other hand, Toribatake *et al.*[5] reported that the tip of the conus medullaris was located equally at the middle third of the L1 vertebral body level and at the L1-2 intervertebral disc level. Their study included patients with OLF, disc herniation, and vertebral fracture of the spine.

Generally, the epiconus is located at the T12 vertebral body level, while the conus medullaris is located from the T12–L1 intervertebral disc level to the L1 vertebral body level.[3,4] Most patients in previous studies showed OLF, disc herniation, or vertebral fracture of the spine.[5] For cases with vertebral fracture, the level of the lumbar segment of spinal cord may vary due to shortening of the total length of the spine.[6] Subjects in the present study were limited to those with a single OLF without previous vertebral fracture to identify the true level of the lumbar segment of spinal cord.

We considered the reflex center of PTR to be L4 segment of spinal cord and of the Achilles tendon reflex to be S1 segment of spinal cord.[17] With regard to the relationship between PTR and OLF level, all patients with OLF at the T10–11 level showed hyperreflexia of PTR and involvement of the L3 segment of spinal cord proximally. Namely, there was L4 segment of spinal cord at T10–11 level distally (Figure 5, left). On the other hand, most patients with OLF at the T11–12 level showed normal reflex or hyporeflexia and involvement of the L4 segment of spinal cord distally. Namely, there was L4 segment of spinal cord at T11–12 level proximally (Figure 5, right). Therefore, we confirmed the presence of the L4 segment of spinal cord from the T11 vertebral body to the T11-12 intervertebral disc level (Figure 5).

With regard to the relationship between sensory disturbance and OLF level, 3 of 15 (20%) patients with OLF at the T10–11 level showed sensory disturbance of the groin and involvement of the L1 segment of spinal cord distally. On the other hand, 6 of 11 (55%) patients with OLF at the T11–12 level showed sensory disturbance of the lateral part of the lower leg and involvement of the L5 segment of spinal cord distally. Therefore, we confirmed the L5 segment of spinal cord at the T11–12 intervertebral disc level (Figure 6 left, proximal limit of existence of L5 segment of spinal cord: Figure 6, right, distal limit of existence of L5 segment of spinal cord). When the L5 segment of spinal cord occurred at the T11–12 intervertebral disc level, the L4 segment of spinal cord was present from the middle third of the T11 vertebral body to the T11–12 intervertebral disc level (Figure 6).

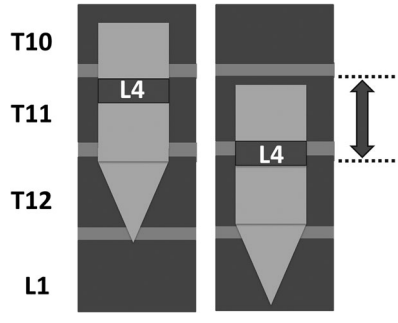

Figure 5 With regard to the relationship between patellar tendon reflex and Ossification of Ligamentum Flavum level, the L4 segment of spinal cord was present from the T11 vertebral body to the T11-12 intervertebral disc level.

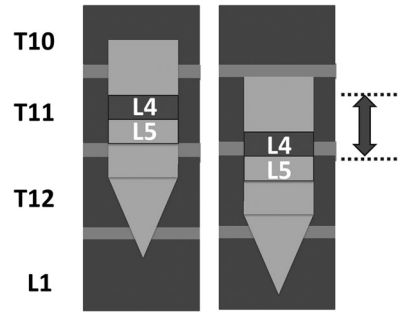

Figure 6 With regards to the relationship between sensory disturbance and Ossification of Ligamentum Flavum level, the L4 segment of spinal cord was present from the middle third of T11 vertebral body to the T11-12 intervertebral disc level.

It is generally accepted that the iliopsoas is mainly innervated by L2 and L3 myotomes, the quadriceps by the L4 myotome, and the tibialis anterior by the L5 myotome.[18–20] With regard to the relationship between motor weakness and OLF level, 8 of 15 (53%) patients with OLF at the T10–11 level showed weakness of the iliopsoas and involvement of the L2 and L3 segment of spinal cords. On the other hand, 4 of 11 (36%) patients with OLF at the T11-12 level showed weakness of the tibialis anterior and involvement of the L5 segment of spinal cord. When the L5 segment of spinal cord occurred at the T11–12 intervertebral disc level in our spine and spinal cord model (Figure 7 left, proximal limit of existence of L5 segment of spinal cord: Figure 7 right, distal limit of existence of L5 segment of spinal cord), L2 and L3 segment of spinal cords were observed at the T10-11 intervertebral disc level. In addition, the L4 segment of spinal cord occurred in the spinal cord from the middle third of the T11 vertebral body to the T11–12 intervertebral disc level (Figure 7).

From our neurologic findings, we confirmed the presence of the L4 segment of spinal cord from the middle third of the T11 vertebral body level to the T11–12 intervertebral disc level. Total spinal length is shortened in the presence of vertebral fracture, although the length of the spinal cord remains unchanged. The impaired level in the spinal cord is slightly distal in this situation. Compared to previous studies, we assessed the location of the L4 segment as being slightly more proximal in the spinal cord. Fushimi et al[1] reported that some

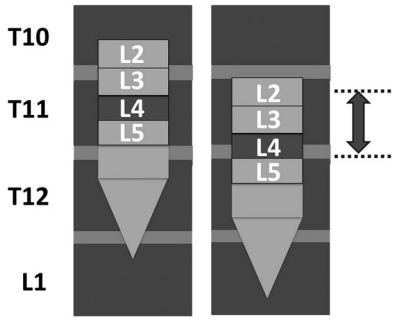

Figure 7 With regards to the relationship between motor weakness and Ossification of Ligamentum Flavum level, the L4 segment of spinal cord was present from the middle third of T11 vertebral body to the T11-12 intervertebral disc level.

patients with LSS at the L3–4 level showed non-hyperreflexia of PTR however they had the thoracolumbar junction disorders at the T10–11 level. These patients had showed hyperreflexia of PTR after lumbar decompressive surgery. We revealed the presence of the L4 segment of spinal cord from the middle third of the T11 vertebral body level to the T11–12 intervertebral disc level in present study. Clinicians should pay attention to the combination of the disorder from the middle third of the T11 vertebral body level to the T11–12 intervertebral disc level for patients with LSS at the L3–4 intervertebral disc level because these patients may show non-hyperreflexia of PTR, sensory disturbance of the L4 dermatome, and weakness of quadriceps. Similarly, clinicians should pay attention to the combination of the disorder at L3–4 intervertebral disc level for patients with thoracic myelopathy because these patients sometimes show non-hyperreflexia of PTR. CTM or MRI at the thoracolumbar junction level should be performed for these patients. A major limitation of the present study was the small number of subjects. Nevertheless, the study findings were very useful for clinicians to diagnose of thoracolumbar junction disorders correctly.

Conclusion

We reviewed neurologic findings caused by a single OLF at the thoracolumbar junction. These revealed the occurrence of the L4 segment of spinal cord from the middle third of the T11 vertebral body to the T11–12 intervertebral disc level. Understanding of the level of the lumbar segment of spinal cord helped clinicians to diagnose thoracolumbar junction disorders correctly.

Conflict of interest statement

The authors declare no conflict of interest.

References

1 Fushimi K, Miyamoto K, Hioki A, Hosoe H, Takeuchi A, Shimizu K. Neurological deterioration due to missed thoracic spinal stenosis after decompressive lumbar surgery. A report of six cases of tandem thoracic and lumbar spinal stenosis. Bone Joint J 2013;95B(10):1388–91.
2 Hioki A, Miyamoto K, Hosoe H, Fukuta S, Shimizu K. Two stage decompression for combined epiconus and cauda equine syndrome due to multilevel spinal canal stenosis of the thoracolumbar spine: a case report. Arch Orthop Trauma Surg 2008;128(9):955–8.
3 Elsberg C. Diagnosis and treatment of surgical disease of the spinal cord and its membranes. Philadelphia: WB sanders; 1916. p. 30–8.
4 Hollinshead WH. Anatomy for surgeons. Vol.3: The back and limbs. New York, San Francisco, London: Harper & Row; 1969. p. 180–6.
5 Toribatake Y, Baba H, Kawahara N, Mizuno K, Tomita K. The epiconus syndrome presenting with radicular-type neurological features. Spinal Cord 1997;35(3):163–70.
6 Hamanishi C, Horikoshi M, Tanaka K. Distribution of the conus medullaris on the MRI. The Central Japan journal of orthopaedic and traumatic surgery. 1994;37(3):695–6.
7 Sato K, Kikuchi S. [An anatomic study of the segment of spinal cordation in the thoracolumbar spine]. Spine spinal cord. 1996;9(12):947–51. Japanese.
8 Goto N. [Macroscopical observation of the spinal cord and segmental lengths]. Spine spinal cord. 1988;1(8):677–8. Japanese.
9 Ko HY, Park JH, Baek SY. Gross quantitative measurements of segment of spinal cords in human. Spinal Cord 2004;42(1):35–40.
10 Brain L, Walton J. Brain's disease of the nervous system, 7th ed. London: Oxford University Press; 1969. p. 40–3.
11 Soleiman J, Demaerel P, Rocher S, Maes F, Marcahal G. Magnetic resonance imaging study of the level of termination of the conus medullaris and the thecal sac: influence of age and gender. Spine 2001;30(16):1875–80.
12 Macdonald A, Chatrath P, Spector T, Ellis H. Level of termination of the spinal cord and the dural sac: A magnetic resonance study. Clin Anat 1999;12(3):149–52.
13 Lee CH, Seo BK, Choi YC, Shin HJ, Park JH, Jeon HJ, *et al.* Using MRI to evaluate anatomic significance of aortic bifurcation, right renal artery, and conus medullaris when locating lumbar vertebral segments. Am J Roentgenol 2004;182(5):1295–300.
14 Saifuddin A, Burnett S.J.D., White J. The variation of position of the conus medullaris in an adult population: a magnetic resonance imaging study. Spine 1998;23(13):1452–6.
15 Belmont PJ Jr, Kuklo TR, Taylor KF, Freedman BA, Prahinski JR, Kruse RW. Intraspinal anomalies associated with isolated congenital hemivertebra: the role of routine magnetic resonance imaging. J Bone Joint Surg Am 2004;86-A(8):1704–10.
16 Morimoto T, Sonohata M, Kitajima M, Konishi H, Otani K, Kikuchi S, *et al.* The termination level of the conus medullaris and lumbosacral transitional vertebrae. J Orthop Sci 2013;18(6):878–84.
17 Urano M, Oda H, Taguchi T, Tominaga T, Otani T, Toyoda K, *et al.* Multivariate analysis of clinical findings in lumbar disc herniation. Orthop Surg Traumatol. 1992;40(4):1477–9.
18 Wilborurn ASA, Aminoff MJ. AAEM minimonograph 32: The electrodiagnostic examination in patients with radiculopathies. Muscle Nerve. 1998;21(12):1612–31.
19 Young A, Getty J, Jackson A, Kirwan E, Sullivan M, Parry CW. Variations in the pattern of muscle innervation by the L5 and S1 nerve roots. Spine 1983;8(6):616–24.
20 Tsao BE, Levin KH, Bodner RA. Comparison of surgical and electrodiagnostic findings in single root lumbosacral radiculopathies. Muscle Nerve 2003;27(1):60–4.